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Investigations to introduce the probability of detection method for ultrasonic inspection of hollow axles at Deutsche Bahn

Mato Pavlovic[a]*, Andreas Zoëga[b], Christina Zanotelli[a] Jochen H. Kurz[b]

[a]*Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin, Germany*
[b]*DB Systemtechnik GmbH, Bahntechnikerring 74, 14774 Brandenburg-Kirchmöser, Germany*

Abstract

The vast experience with the automated, ultrasonic system for the inspection of hollow railway axles used by Deutsche Bahn shows that much smaller flaws are detectable than required. This results in a number of false calls. False calls lead to unnecessary demounting and disassembling of wheelsets, which generates unnecessary additional costs. In order to adjust the sensitivity of the inspection system to reduce the number of false calls without compromising safety, the capability of the system to detect cracks needs to be comprehensively established. This capability can be quantified by using probability of detection (POD) curves for the system. The multi-parameter POD model makes it possible to include several factors that influence the crack detection in the analysis. The analysis presented in this paper shows that crack position, orientation, depth extension, and shape as well as the geometry of the axle all have influence on the ultrasonic response amplitude. For future work, calculation of the POD using multi-parameter POD model with these parameters is planned.

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Keywords: Non-destructive testing; NDT; Ultrasonic; Cracks; Reliability; Probability of Detection; POD

1. Introduction

Deutsche Bahn uses mechanized ultrasonic inspection systems to inspect hollow railway axles. Currently, about 140 devices are used to inspect more than 130,000 axles per year. Current testing results show that the devices detect even smaller flaws than required by the standard. This oversensitivity is resulting in a number of false calls.

* Tel.: +49-30-8104-4616.
E-mail address: mato.pavlovic@bam.de

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The sources of false calls are various. Accumulations of dirt, press fits and flawed coatings can all generate ultrasonic indications. False calls lead to unnecessary demounting and disassembling of the wheelsets which generates unnecessary additional costs. The goal of the joint project between DB-Sytemtechnik and BAM is to determine the capability of the ultrasonic system to detect flaws. Once determined, the sensitivity of the inspection can be adjusted so that the number of false calls is reduced.

Indications from non-destructive testing (NDT) systems, especially when trying to detect very small defects, are inconsistent. Therefore, in applications where a missed flaw can have catastrophic consequences, the reliability of the system has to be established. The probability of detection (POD) curve is considered to be a standard tool to quantify the reliability of NDT [1]. A signal response model [2] assumes that the response signal from the defect is linearly correlated with the flaw size with normally distributed deviations. Setting the decision threshold, the POD and a lower 95% confidence bend are calculated from this correlation. The $a_{90/95}$ point determines the limit of reliable use of the NDT system. When there are more factors that influence the POD of the flaw significantly, the signal response model is not applicable any more. The multi-parameter POD model, allows several influencing factors to be included in the analysis and enables the POD to be expressed as a function of these factors [3].

2. Automated system for the inspection of hollow axles

One of the ultrasonic inspection systems for the inspection of hollow railway axles used by Deutsche Bahn is shown in Fig. 1. The system is docked to the side of the axle and the probe module is pushed into the borehole. The axles are inspected from the bore surface.

Fig. 1. Example for a mechanized ultrasonic inspection system for the inspection of hollow axles used by Deutsche Bahn

The section view of the axle with the probe module inside is illustrated in Fig. 2. The ultrasonic transducers are located in the probe module. The electro-mechanical drive moves the probe module in the axial direction and at the same time it rotates around the longitudinal axis, so that the transducers describe a helical path. The electro-mechanical drive also delivers coupling oil to the probe module and transfers the signals from the transducers to the control unit. Several transducers with different angles of incidence are mounted in the probe head with the aim of detecting cracks on the outer surface of the axle. The detection of the planar, surface breaking flaws that are perpendicular to the surface is mainly based on the corner reflection effect. The ultrasonic wave that hits the back surface of the inspected component under a favorable angle is reflected to the flaw and then back to the transducer. Since the outer surface of the axle has a variable diameter, the cracks which propagate perpendicular to the surface of the axle, will have a 90° angle to the axis only in the regions of the axle where the diameter is constant. The angle between the flaw and the ultrasonic wave will have an influence on the corner reflection effect and therefore also on the detectability of the flaw. The transition region between the wheel seat and the body of the axle is considered particularly susceptible to cracking. The investigation of the detectability of cracks by the ultrasonic inspection system was concentrated in this region.